REMARKS

I. Introduction

By the present Amendment, claims 1-5 have been cancelled. Claims 6-12 are newly presented for consideration. Accordingly, claims 6-12 remain pending in the application. Claims 6, 8, and 9 are independent.

II. Office Action Summary

In the Office Action of December 23, 2008, claims 1-3 were rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. Patent No. 6,193,659 issued to Ramamurthy et al. ("Ramamurthy ") in view of U.S. Patent No. 6,497,665 issued to Hunt et al. ("Hunt"). Claims 4 and 5 were rejected under 35 U.S.C. §103(a) as being unpatentable over Ramamurthy in view Hunt, and further in view of U.S. Patent No. 5,944,666 issued to Hossack et al. ("Hossack").

The cancellation of claims 1-5 has rendered the foregoing grounds of rejection moot. By the present Amendment, Applicants have introduced claims 6-12 for consideration. As will be discussed in greater detail below, the features recited in these claims are not shown or suggested by the art of record.

Independent claim 6 is newly presented and defines an ultrasonic imaging device for transmitting/receiving ultrasonic pulse to/from a living body in which microbubbles for contrast are introduced, and forming a contrast image of the inside of the living body, The ultrasonic imaging device comprises:

> a transmit beamformer for generating a transmit pulse;
>
> a receive beamformer for generating a time-series reception echo signal with adding receive signals, to each of which a delay time is given for generating receiving sensitivity having directivity;
>
> an adder for summing the time-series reception echo signals;

and

a transmit/receive sequence controller for controlling the transmit beamformer and the receive beamformer;

wherein the transmit/receive sequence controller controls the transmit beamformer and the receive beamformer to perform transmitting/receiving operations N times (N= an integer of three or greater) by controlling a sampling frequency of the transmit pulse being an integer-multiple of N with respect to a maximum frequency of frequency components of the transmit pulse, and N pieces of transmission pulse waves having a common envelope signal and different waveforms under a transmission/reception wave focus condition, and controlling carrier waves of the transmission pulse waves so as to vary in phase by 360°/N from one wave to a next wave, and receiving returned ultrasonic waves as N pieces of the time-series reception echo signals; and

wherein said adder sums the N pieces of the time-series reception echo signals so as to output an output signal as a signal indicative of a spatial distribution of the microbubbles.

The ultrasonic imaging device of independent claim 6 includes a transmit beamformer for generating a transmit pulse, and a receive beamformer for generating time-series reception echo signals, to each of which a delay time is given for generating receiving sensitivity having directivity. An adder is provided for summing the time-series reception echo signals, while a transmit/receive sequence controller controls the transmit beamformer and the receive beamformer. According to independent claim 6, the transmit/receive sequence controller controls the transmit beamformer and the receive beamformer to perform transmitting/receiving operations N times, where N is an integer greater than or equal to 3. This is done by controlling a sampling frequency of the transmit pulse being an integer-multiple of N with respect to a maximum frequency of frequency components of the transmit pulse, and N pieces of transmission pulse waves having a common envelope signal and different waveforms under a transmission/reception wave focus condition, and controlling carrier waves of the transmission pulse waves so as to vary in phase by

360°/N from one wave to a next wave, and receiving returned ultrasonic waves as N pieces of the time-series reception echo signals. Furthermore, the adder sums the N pieces of time-series reception echo signals and outputs a signal indicative of a spatial distribution of the microbubbles. At least one benefit achieved by the imaging device of independent claim 6 is an ability to resolve non-linear problems associated with the transmit amplifier, because the sampling frequency of the transmit pulse is set to an integer multiple of N with respect to a maximum frequency of components in the transmit pulse.

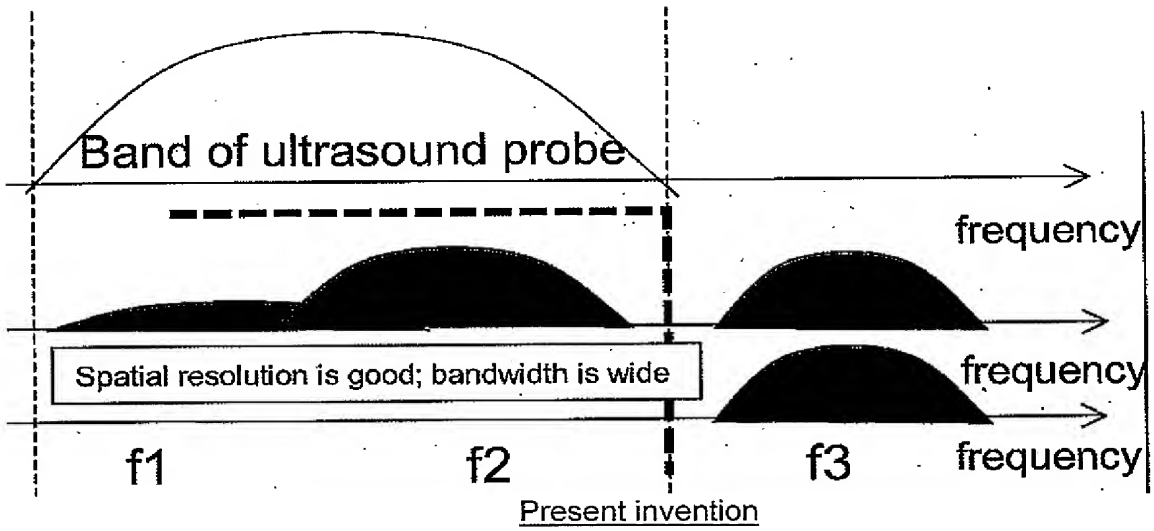
More particularly, according to the present invention, it becomes possible to suppress transmission/reception sensitivity to components from the fundamental wave to the harmonic wave of the ultrasonic echo signal from the soft tissue in the living body. When N is an integer = 3, for example, each of the phase differences is 120 degrees. Since the phase of the second harmonic wave is double that of the phase of the fundamental wave, the phases of the fundamental wave and the second harmonic wave from the living body becomes zero when the phase of the carrier wave is zero. When the phase of the carrier wave is 120 degrees, the phase of the fundamental wave becomes 120 degree, but the second harmonic wave is generated at 240 degrees. Finally, when the phase of the carrier wave is 240 degree, the phase of the fundamental is 240 degrees, but the second harmonic wave has a phase of 120 degrees. Thus, if the 3 pieces of time-series reception echo signals are summed, the result becomes zero. Accordingly, it becomes possible to suppress the fundamental wave to the (N-1) harmonic component from the living body.

The phase of the echo signal generated by being scattered by the microbubble contrast medium, however, is influenced by the amplitude of the envelope due to its strong non-linear resonance characteristic. Furthermore, it does not have a predetermined relationship to the phase of the transmission signal carrier wave. As illustrated in Figs. 6(a) - 6(c), the echo signals scattered from the microbubbles have different waveforms and no constant relations to phases 0, 120, and -120 (240) degrees. Consequently, even if three echo signals obtained by performing the transmitting/receiving operation three times while varying the phase of the transmission pulse carrier wave by 120 degree are summed, the components which are not cancelled out will remain.

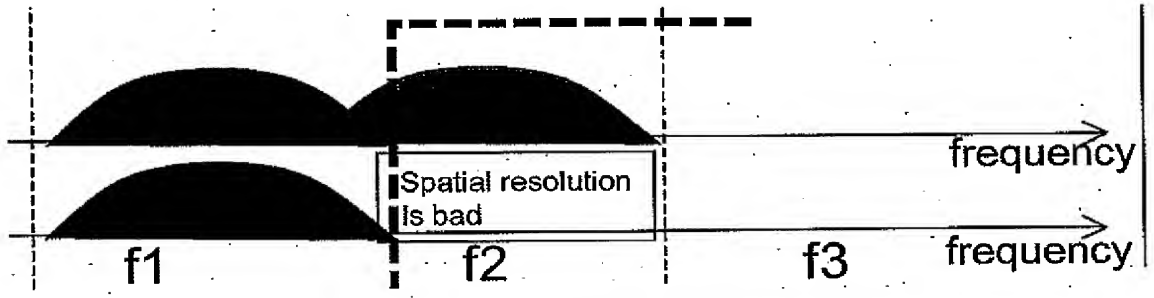
According to the present invention, however, the adder sums the N-series reception echo signal and supplies an output signal indicative of the spatial distribution of the microbubbles. Accordingly, it is possible to obtain an ultrasonic image in which the contrast medium is clearly distinguished from the soft tissue.

The Office Action had previously indicated that the combination of cited references disclosed all the features of the claimed invention. Applicants' review of the cited references, however, has failed to reveal any disclosure or suggestion for the features recited in the newly presented claims.

Ramamurthy discloses an ultrasonic diagnostic imaging apparatus capable of improving contrast agent harmonic imaging as well as tissue harmonic imaging, depending upon the phase shift selected. Ramamurthy sums the received waves by selecting 0 or 90 degree for the phase of a transmit pulse of each transducer element. As illustrated in the figure below, it is not possible for Ramamurthy to separate the fundamental component from the living body (f1).



Present invention



Ramamurthy

As noted in the Office Action, "the summed acoustic waveform is shaped to suppress ultrasonic energy in a wide band centered at the harmonic frequency." See page 3, lines 6, 7. Thus, in Ramamurthy, the harmonic component (f2) from the living body is suppressed, but the fundamental component (f1) is not suppressed. More particularly, by summing up the transmitted

waves based on the transmit pulse having 0 or 90 degree phase, the second harmonic component becomes 0 and 90x2 degrees, and is eliminated. This tissue second harmonic field, however, has a null of the beam axis. See col. 17, lines 36-

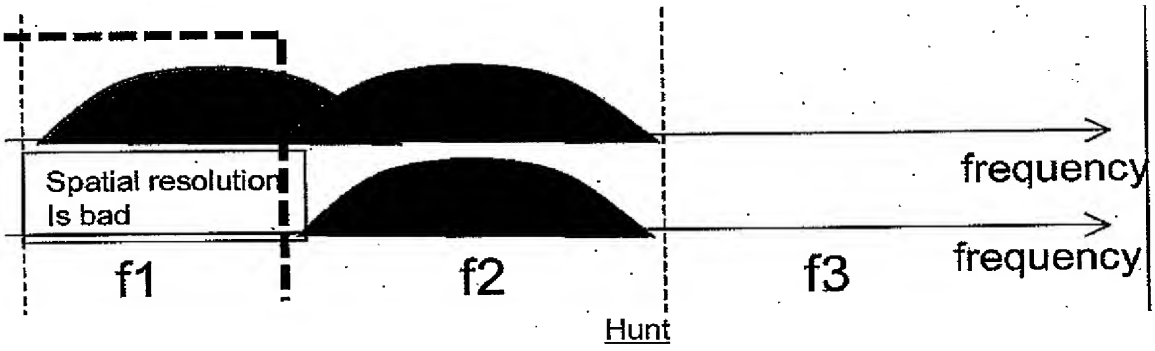
37. There is little tissue second harmonic signal present in the ultrasound line data (column 17, lines 39-41). However, the fundamental component of the living body remains because two phase components do not eliminate each other. The fundamental field level on axis is typically only mildly decreased (by about 3dB), and the fundamental field levels on axis remain sufficiently strong. See col. 17, lines 31-33 and lines 41-42. Since the fundamental component (f1) remains present, it is necessary to use a filter to eliminate the f1 component from the living body. Such filters, however, typically have narrow BAND-pass characteristics or sharp band-cutoff characteristics (See the paragraph [0016] of US2008/0228076). By narrowing the bandwidth to eliminate the fundamental component (f1), part of the second harmonic component is also eliminated, thereby resulting in reduced the spatial resolution.

According to the present invention, however, it is possible to eliminate the fundamental component and the (N-1) harmonic component (for example, the second harmonic component in N=3) without the use of any filters. It is also possible to use wide band width of the signals from the microbubbles, and the second harmonic component from the microbubbles is not eliminated. Accordingly, the spatial resolution is improved. In any event, Ramamurthy fails to provide any disclosure or suggestion for features recited in independent claim 6, such as:

> wherein the transmit/receive sequence controller controls the transmit beamformer and the receive beamformer to perform transmitting/receiving operations N times (N= an integer of three or greater) by controlling a sampling frequency of the transmit pulse being an integer-multiple of N with respect to a maximum frequency of frequency components of the transmit pulse, and N pieces of transmission pulse waves having a common envelope signal and different waveforms under a transmission/reception wave focus condition, and controlling carrier waves of the transmission pulse waves so as to vary in phase by 360°/N from one wave to a next wave, and receiving returned ultrasonic waves as N pieces of the time-series reception echo signals; and

wherein said adder sums the N pieces of the time-series reception echo signals so as to output an output signal as a signal indicative of a spatial distribution of the microbubbles.

Hunt discloses an ultrasonic irradiation that is executed with using a first and second amplifier. The projected response may be subtracted from the stored second response (step216), so that the linear responses are removed leaving the nonlinear responses from the contrast agent and the surrounding issue. See col. 2, lines 58-60, and col. 7, lines 43-52. As illustrated below, Hunt eliminates the fundamental component (f1) from the living body, but the second component is not eliminated.



Hunt

In Hunt, it is necessary to eliminate the second harmonic component with a filter. If the second harmonic component is eliminated with a filter, however, the bandwidth of the signal becomes narrow and the part of the fundamental component of the microbubbles is also eliminated. Consequently, the spatial resolution is decreased. Similar to Ramamurthy, Hunt fails to provide any disclosure or suggestion for the features that are now recited in independent claim 6.

It is therefore respectfully submitted that independent claim 6 is allowable over the art of record.

Independent claims 8 and 9 are newly presented and also recite features that are similar to those recited in independent claim 6. Accordingly, these claims are believed to be allowable over the art of record.

Clams 7 and 10-12 depend from independent claims 6 or 9, and are therefore believed allowable over the art of record.

For the reasons stated above, it is respectfully submitted that all of the pending claims are now in condition for allowance. Therefore, a Notice of Allowance is believed in order, and courteously solicited.

If the Examiner believes that there are any matters which can be resolved by way of either a personal or telephone interview, the Examiner is invited to contact Applicants' undersigned attorney at the number indicated below.

AUTHORIZATION

Applicants request any shortage or excess in fees in connection with the filing of this paper, including extension of time fees, and for which no other form of payment is offered, be charged or credited to Deposit Account No. 01-2135 (Case: 520.46411X00).

Respectfully submitted,

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Dated: May 26, 2009